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INFLUENCE OF THE WEATHER ON THE YIELD OF CROPS.

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[Weather Bureau, Washington, November 25, 1922.]

In the *Yearbook of the Department of Agriculture* for 1903, the writer presented certain charts or graphs showing the relation between the rainfall during the summer months, both separately and in combination, and the yield of corn in the important corn growing States.

In the Monthly Weather Review for February, 1914, the effect of the weather on the yield of corn was presented, and in the same publication for May, 1915, the effect of the weather on the yield of potatoes was shown. In these last two papers, as well as in other similar studies made from time to time, the close relation between the weather of certain periods and the yield of crops was expressed by the correlation coefficient.

Both methods are useful. The first, to present the relation between two factors graphically; the second, to show the kind of weather that has the greatest influence in varying the yield of a crop, as well as the most critical period of growth, especially when preceded by the dot charts and supported by the partial correlation.

A thorough study of the subject has indicated to many the possibility of predicting the yield of crops from a knowledge of antecedent weather conditions. This may be done, of course, through regression equations, although the interrelation of the various weather factors and the differences in their effects through different periods of growth are extremely complicated and possibly await entirely satisfactory resolution.

The writer and his associates have attacked the question from many different angles. Long ago we were convinced that the calendar month covers too long a period of time and is too arbitrary in its limits to be used successfully. It has been used, however, because climatological data are tabulated and published in monthly units. To tabulate these data in units of shorter periods entails an enormous amount of work, as every one knows who has made the attempt.

In our study of weather and corn we tabulated rainfall and temperature data by ten-day periods, for central Ohio, with fairly satisfactory results.

Within the past two years the Division of Agricultural Meteorology of the Weather Bureau has obtained the daily average rainfall, temperature, and sunshine values for parts of States, or whole States, in important crop districts, and has summarized these daily values into *weekly* averages and totals. The highly satisfactory results given below are based on these weekly values, and show pretty conclusively that the week is probably the most convenient unit of time to use, even if the clerical work is so large.

Further, these studies have emphasized the fact that the important stages of development reached by a crop which varies in different years, must be found, but there is a marked dearth of information of this character, caused partly by lack of intensive study, but also because of the indefinite results that come from attempted correlations between general crop production on the agricultural scale and the reported weather conditions derived from the general meteorological observations. This should be remedied by the inauguration of closely related observations of weather conditions with conditions of growth and yield, including phenological observations in connection with important crops at all the agricultural experiment stations, and possibly elsewhere.

The results recently secured from studies of existing data giving weather conditions and crop yields have, however, proven so encouraging as to justify a very brief publication with the object of reporting upon the progress being made in formulating the influence of the weather on crop production and reserving, for a future report, the presentation of the full details when the effects of the several factors have been more accurately evaluated, the methods better developed, and the results checked and verified more rigorously than is now possible.

It seems proper at this point to say that studies of this kind are continually vitiated and made difficult by material errors of considerable magnitude in the statistics giving *yield per acre*. Obviously, the whole error in this datum necessarily expresses itself in the form of final error of calculated yield, and also tends to make confusion in, and irrational outcome of, the weather relations tentatively adopted. Such encouraging results were secured by the present method in an initial study of the influence of the weather on oats that the work was extended to the corn crop in north central Illinois, and finally to the cotton crop in South Carolina.

THE RELATION OF WEATHER TO THE YIELD OF OATS.

One of the first districts covered by the daily tabulation of meteorological data was in north-central Illinois, and included the counties of De Witt, Logan, McLean, Macon, Marshall, Mason, Menard, Peoria, Stark, Tazewell, and Woodford, 11 in all. The period covered was from March 1 to August 31, inclusive, for the 27 years from 1894 to 1920, inclusive.

The temperature data were from three well-distributed stations in this area, while the rainfall averages were obtained from all the rainfall stations in the district, eight in number. Weekly total precipitation values were determined from these daily averages, and weekly average maximum, minimum, and mean temperatures calculated for each year.

The average yield of oats for the 11 counties for each year was obtained from the figures published by the United States Department of Agriculture. These yields vary from 48 bushels to the acre in 1917, to 16.2 bushels in 1895. The yield for the 27 years averaged 34.8 bushels.

Charts were made showing graphically the variations of temperature and precipitation from the normal for each week of each year. These were grouped by yield values in order to determine by inspection, if possible, how the weather during the years of large yields differed from those with small yields.

Weekly weather and crop bulletins were studied to determine favorable and unfavorable conditions for oats, as well as to obtain dates of seeding, germination, heading, ripening, and harvesting for each year as far as possible. These data were obtained from other sources also.

WEATHER INDEX VALUES.

Many charts, diagrams, and mathematical calculations were made to determine critical periods, workable equations, and the like. These, as well as previous studies, showed that the oat plant does best in comparatively cool, moist climates; that in northern Ohio, Indiana, and Illinois, and in Iowa, April should be moderately dry to insure a good seed bed, and comparatively warm for quick germination; also that June should be cooler and slightly wetter than normal to allow for proper heading and ripening, as hot and dry weather while the heads are filling is decidely unfavorable. It was found, further, that a cold winter has a favorable influence on the yield.

A long effort to establish workable, empirical relations between both favorable and unfavorable weather conditions led to a decision to consider only *unfavorable* weather; in other words, to consider all weather favorable that was not plainly unfavorable. This idea had been given only slight consideration heretofore, but it has been a very useful factor in the present effort to estimate the yield of crops from the weather conditions.

In applying this method a careful study is made of the weather conditions over the region covered, week by week, from the 1st of March to the 31st of August, and year by year. An estimate is made of the unfavorable effect of features of the weather which are considered detrimental, and a sum is obtained of these harmful effects, which becomes the *weather index* for the year. The results in the present case are shown in Table 1, where column 2 gives the weather index and column 3 the yield of oats for each year.

TABLE 1.—*Influence of the weather on the yield of oats in north-central Illinois for the period 1894 to 1920, inclusive.*

[In bushels per acre.]

1	2	3	4	5	6	7
Year.	Weather index w.	Yield Y.	w^2.	$w \times Y$.	Calculated yield y.	Variation from actual v.
1894	17	40.5	289	688.5	39.5	−1.0
1895	40	16.2	1,600	648.0	16.8	+0.6
1896	28	29.9	784	837.2	28.6	−1.3
1897	21	36.9	441	774.9	35.6	−1.3
1898	32	24.7	1,024	790.4	24.7	0
1899	12	44.5	144	534.0	44.4	−0.1
1900	13	43.6	169	566.8	43.5	−0.1
1901	25	33.1	625	827.5	31.6	−1.5
1902	15	41.8	225	627.0	41.5	−0.3
1903	28	29.1	784	814.8	28.6	−0.5
1904	26	32.3	676	839.8	30.6	−1.7
1905	16	41.3	256	660.8	40.5	−0.8
1906	27	30.5	729	823.5	29.6	−0.9
1907	29	28.5	841	826.5	27.7	−0.8
1908	36	20.7	1,296	745.2	20.7	0
1909	22	36.1	484	794.2	34.6	−1.5
1910	23	35.8	529	823.4	33.6	−2.2
1911	28	30.4	784	851.2	28.6	−1.8
1912	11	45.8	121	503.8	45.4	−0.4
1913	32	24.4	1,024	780.8	24.7	+0.3
1914	24	34.9	576	837.6	32.6	−2.3
1915	11	45.5	121	500.5	45.4	−0.1
1916	20	37.7	400	754.0	36.5	−1.2
1917	8	48.0	64	384.0	48.4	+0.4
1918	16	41.3	256	660.8	40.5	−0.8
1919	29	27.7	841	803.3	27.7	0
1920	19	38.7	361	735.3	37.5	−1.2
Sums	608	939.9	15,444	19,433.8		
Average	22.5	34.8				0.82

From the weather index and yield values, a regression equation, $y=a+bw$, was calculated by the method of least squares, as shown by the table, and a was found to be 56.3 and b -0.988; w is the index number, and y the yield as calculated by the equation; v shows the variations of the calculated yield from the actual.

The average variation of the calculated yield from the actual for the 27 years, as shown by column 7, is only 0.8 bushels per acre, while the greatest variation was -2.3 bushels in 1914. These values are only 2 and 6 per cent, respectively, of the average yield. The correlation coefficient for the weather index and the yield figures is 0.994 ± 0.012.

The regression equation indicates that the maximum yield of oats, averaged for the whole area under discussion, need not be expected to reach above 56.3 bushels per acre.

Testing the value of the equation.—To test the value of a study of this character, the equation must be applied to a period not included in evolving the equation. This was done for 1921, with the result that the calculated yield was 24.7 bushels per acre, while the actual yield was 24.9 bushels, a variation of only 0.2 bushels.

To further test the accuracy of the figures and also to determine whether they are applicable in other districts, they were applied to the whole State of Illinois, as well as to the States of Ohio and Iowa, for the four years 1918 to 1921, inclusive, giving the following results:

TABLE 2.—*Weather and the yield of oats, 1918 to 1921.*

[Bushels per acre.]

Year.	Yield.	Calculated yield.	Variation.	Per cent.
ILLINOIS.				
1918	44.0	45.4	+1.4	3
1919	30.0	32.8	+2.8	9
1920	40.0	37.5	−2.5	6
1921	26.0	24.7	−1.3	5
OHIO.				
1918	44.0	43.7	−0.3	0.7
1919	33.5	33.0	−0.5	1
1920	44.2	43.2	−1.0	2
1921	23.0	26.6	+3.6	16
IOWA.				
1918	39.4	38.5	−0.9	2
1919	34.7	36.5	+1.8	5
1920	39.1	38.3	−0.8	2
1921	26.0	24.2	−1.8	7

In making up the weather index for Iowa, only half as much weight was given to winter temperatures as in the other States, but otherwise the same values were used, showing that the laws are applicable in most of the main oat-growing section, in this latitude at least.

The weather data for these States were obtained from weekly charts in the National Weather and Crop Bulletins, hence are not so complete or definite as if the exact daily or weekly averages for the State were calculated. It is not surprising, therefore, that some of the variations in Table 2 are greater than in the small district in Illinois where daily averages were obtained. Figure 1 shows the variation of the calculated from the recorded yield of oats in north-central Illinois for each year from 1894 to 1921. The yield for 1921 was calculated in advance. Figure 2 shows the relation between the actual and calculated yields of oats for 1918 to 1921 in Illinois, Ohio, and Iowa, respectively.

THE RELATION OF THE WEATHER TO THE YIELD OF CORN.

Corn is a sun-loving crop of tropical origin; but it is so flexible in its requirements and so readily adapts itself to its surroundings that it is successfully grown over wide climatic ranges.

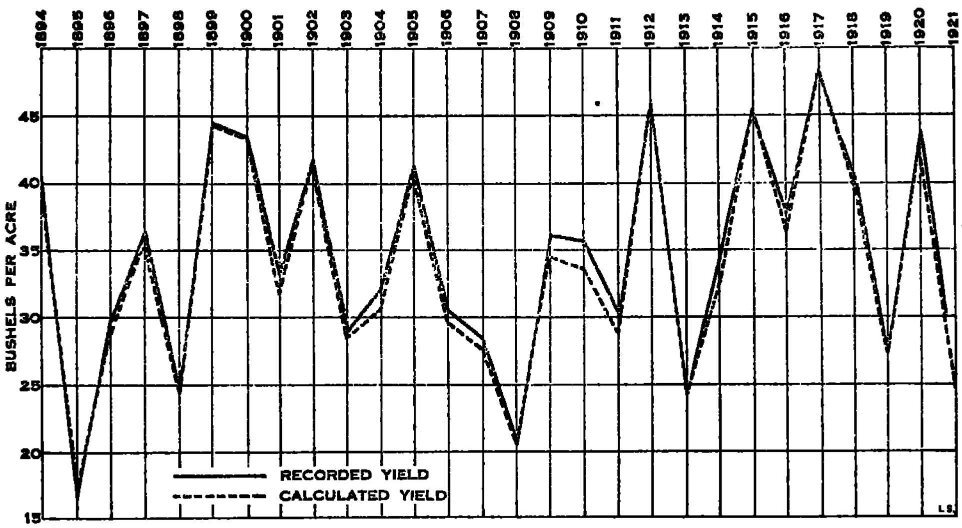

FIG. 1.—The relation of the actual to the calculated yield of oats in north-central Illinois. The year 1921 was calculated in advance.

The region of most intensive cultivation in the United States is where the summer temperature averages from 70° to 80° and where the annual precipitation is between 25 and 50 inches and the rainfall for July and August is about 7 or 8 inches.

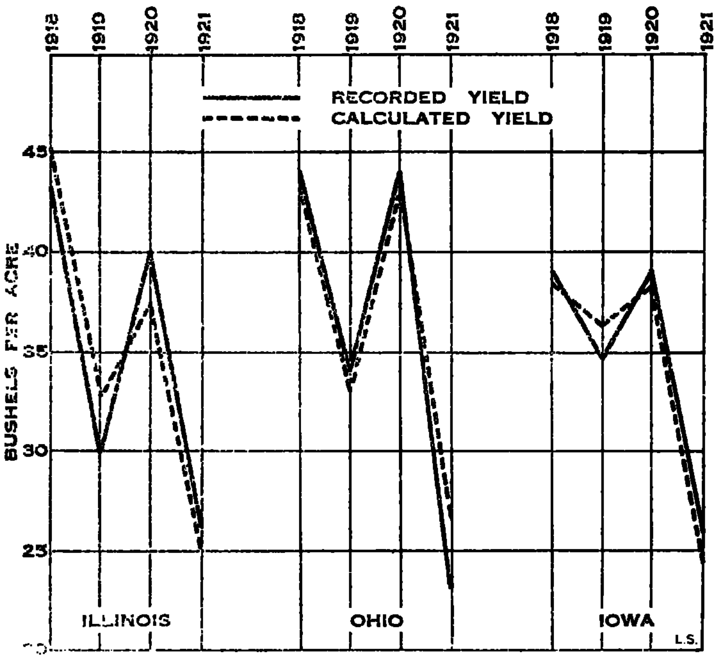

FIG. 2.—The three diagrams show the relation between the actual and calculated yield of oats for 1918 to 1921 in Illinois, Ohio, and Iowa, respectively. The calculated yield values were based on the equation evolved from the north-central Illinois data, 1894 to 1920.

Previous studies by the writer and others show that in the northern Ohio and central Mississippi Valleys the most important weather factor in varying the yield of corn from year to year is the amount of rainfall during that stage of growth represented by the month of July. At the same time it is plain that the yield in any district can not be predicted from a knowledge of the rainfall during July alone, but that other factors must be considered.

Mr. J. B. Kincer has obtained a very high correlation between the weather and corn yield by considering the temperature during June and the rainfall in July, but even then other factors must be taken into account if an attempt is made to predict the yield.

The writer, therefore, after completion of the successful effort to predict the yield of oats by the use of a weather index, as indicated above, decided to make an exhaustive study of weather and corn yield for the same area in north-central Illinois as was used in the study of oats. The yield figures were obtained from the Department of Agriculture, and the same weekly meteorological data used that were tabulated for the oats study.

Large charts were prepared for each year and an effort made to evolve a weather index that could be used in correlating the yield with the previous weather. As in the case of oats, all available facts were obtained to show the development of the corn crop each year and the weather effects during these different periods.

Profiting by the experience in the study of weather and oats, a weather index based on unfavorable conditions alone was obtained for each year that could be used in evolving a regression equation.

Believing that the most critical periods in the growth of corn in the latitude or area covered are earlier than August, and wishing to ascertain whether it might be possible to predict the yield of corn by the close of July, the weather data up to the first of August only were considered.

Table 3 gives the weather index (w) in column 2, while column 6 shows the calculated yield (y), and column 7 the variation of the calculated yield from the actual (Y).

TABLE 3.—*Influence of the weather on the yield of corn in north-central Illinois for the period 1894 to 1920, inclusive.*

[In bushels per acre.]

1	2	3	4	5	6	7
Year.	Weather index w.	Yield Y.	w^2	$w \times Y$.	Calculated yield y.	Variation from actual v.
1894	19	34.7	361	659.3	35.4	+0.7
1895	15	38.7	225	580.5	38.9	+0.2
1896	10	43.6	100	536.0	43.3	−0.3
1897	18	35.4	324	637.2	36.3	+0.9
1898	28	28.0	784	784.0	27.5	−0.5
1899	14	40.6	196	568.4	39.8	−0.8
1900	12	42.3	144	507.6	41.6	−0.8
1901	32	24.6	1,024	787.2	24.0	−0.6
1902	11	42.7	121	469.7	42.4	−0.3
1903	16	37.1	256	593.6	38.0	+0.9
1904	16	37.3	256	596.8	38.0	+0.7
1905	13	41.4	169	538.2	40.7	−0.7
1906	19	34.0	361	646.0	35.4	+1.4
1907	17	36.4	289	618.8	37.2	+0.8
1908	24	31.8	576	763.2	31.0	−0.8
1909	16	36.9	256	590.4	38.0	+1.1
1910	12	42.4	144	508.8	41.6	−0.8
1911	14	40.1	196	561.4	39.8	−0.3
1912	13	41.3	169	536.9	40.7	−0.6
1913	28	27.9	784	781.2	27.5	−0.4
1914	21	32.6	441	684.6	33.6	+1.0
1915	6	47.2	36	283.2	46.8	−0.4
1916	25	31.4	625	785.0	30.1	−1.3
1917	11	42.7	121	469.7	42.4	−0.3
1918	11	43.0	121	473.0	42.4	−0.6
1919	15	38.6	225	579.0	38.9	+0.3
1920	17	36.1	289	613.7	37.2	+1.1
Sums	453	1,008.8	8,593	16,053.4	1,008.5	....
Means	16.78	37.36	....	....	37.35	0.69

The equation used in calculating the values, y, in column 6, is—

$$y = a + bw$$

in which w is the weather index. The most probable values of the constants a and b are given by the solution of two normal equations. (See any good text on Methods of Least Squares.) Making the calculation these constants become a, 52.1, and b, —0.8784.

Introducing the values found in the present case the equation becomes—

$$y = 52.1 - 0.8784\ w$$

This equation gives the calculated yield, y, to be expected from the final value, w, found from the summation of adverse weather conditions.

The correlation coefficient for w and Y is—

—0.9797; probable error, ±0.012.

The figures in column 7, Table 3, show that the average variation of the calculated from the recorded yield was 0.7 bushels per acre, and the greatest variation +1.4 bushels in 1906.

The calculated average yield for these counties in 1921 was 37.2 bushels per acre. The recorded yield was 37.5

Figure 3 shows the variation of the calculated from the actual yield of corn in north-central Illinois, for each year from 1894 to 1921. The yield for 1921 was calculated in advance.

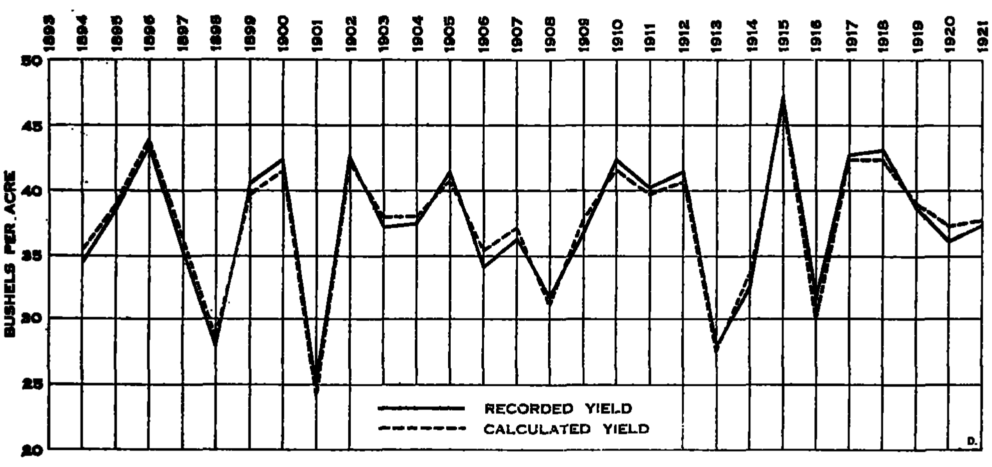

FIG. 3.—The variation of the calculated from the actual yield of corn in north-central Illinois for each year from 1894 to 1921. The yield for 1921 was calculated in advance.

THE RELATION OF THE WEATHER TO THE YIELD OF COTTON.

Cotton is such an important crop that a good deal of time has been given to the study of the effect of weather on the yield. Two facts have been ascertained:

1. The general weather conditions that are favorable or unfavorable during its development, and
2. There is usually too much rain in the eastern part of the cotton belt during the early season of growth and too little rain in the western part during the late season of growth.

Although moderately high correlations can be found between the weather and yield, the opinion has been freely expressed that the cotton plant is so weed-like in its growth and continues to bloom and fruit until the end of the growing season that, unlike corn and other grains, it will never be possible to identify any particular short period when the weather has a dominating influence on the yield.

Some two years ago, however, the writer discovered that, in South Carolina the yield bears a sufficiently close relation to the weather during one week in June to make fairly close predictions possible during most of the years. During the years when the yield was unusually high, and most of the time when the yields were very low, the variation between the predicted and actual yield was considerable, showing that other factors must be taken account of.

With these facts in mind, as well as of the success attained in calculating a weather index that could be closely correlated with oat and corn yields, an attempt was made to handle weather and cotton in the same manner. Further, because there is such a close relation between the weather for one week in June and the yield it was decided to use the weather conditions preceding the first of July in evolving the weather index.

TABLE 4.—*Influence of the weather on the yield of cotton in South Carolina for the period 1899 to 1919, inclusive.*

1	2	3	4	5	6	7
Year.	Weather-Index w.	Yield, pounds per acre Y.	w^2	$w \times Y$	Calculated yield, pounds per acre, y.	Variation from actual yield, r.
1899	12.5	165	156.25	2062.5	169.4	+4.4
1900	12.5	167	156.25	2087.5	169.4	+2.4
1901	14.5	141	210.25	2044.5	138.2	−2.8
1902	10.5	199	110.25	2089.5	200.5	+1.5
1903	11.5	178	132.25	2047.0	185.0	+7.0
1904	9.5	215	90.25	2042.5	216.1	+1.1
1905	9.0	220	81.00	1980.0	223.9	+3.9
1906	12.0	175	144.00	2100 0	177.2	+2.2
1907	10.0	215	100.00	2150.0	208.3	−6.7
1908	9.0	219	81.00	1971.0	223.9	+4.9
1909	10.0	210	100.00	2100.0	208.3	−1.7
1910	9.5	216	90.25	2052.0	216.1	+0.1
1911	5.0	280	25.00	1400.0	286.2	+6.2
1912	10.0	209	100.00	2090.0	208.3	−0.7
1913	8.5	235	72.25	1997.5	231.7	−3.3
1914	7.0	255	49.00	1785.0	255.0	0
1915	10.0	215	100.00	2150.0	208.3	−6.7
1916	13.0	160	169.00	2080.0	161.6	+1.6
1917	10.5	208	110.25	2184.0	200.5	−7.5
1918	7.5	250	56.25	1875.0	247.2	−2.8
1919	8.0	243	64.00	1944.0	239.4	−3.6
Sum	210.0	4375	2197.5	42232.0		
Mean	10	208.33				3.4

The State used in this study was South Carolina. The cotton-yield figures are from the publications of the Department. The average rainfall for all the meteorological stations in the State was calculated for each day from 1899 to 1919. These daily averages were totaled by weeks from March 5 to September 24. The weekly mean temperature, mean minimum temperature, and weekly cloudiness were also calculated for the same period, and the departure from normal obtained for each week.

Charts were prepared and information obtained regarding crop development and weather effects, as was done in studying oats and corn.

After all this and much more preliminary work had been done, a weather index was calculated for each year from 1899 to 1919, inclusive, based on the unfavorable effects of the weather during the period from planting of cotton until the end of June. Only unfavorable conditions were considered. The meteorological factors were rainfall, minimum temperature, and cloudiness.

The weather index for each year is given in column 2, Table 4.

The figures in column 6, Table 4, show the calculated yield of cotton each year based on the equation

$$y = a + bw.$$

The value of the constant a is 364.0, and of the constant b -15.569. The correlation coefficient for w and Y is -0.927, ± 0.0147.

The average variation of the calculated from the recorded yield for the 21 years is 3.4 pounds an acre, while the maximum variation is -7.5 pounds in 1917, or only 3.6 per cent of the yield for that year.

To determine the working value of the equation and the method by which the index numbers are calculated, another member of the office force applied them to the years 1920, 1921, and 1922. The results appear in Table 5.

TABLE 5.—*Test of equation by estimating the yield of cotton in advance in South Carolina.*

1	2	3	4	5	6
Year.	Yield.	Predicted.	Variation.	[1] After allowing for boll-weevil damage.	
				Predicted.	Variation.
1920	254	278.4	+24.4	250.6	−3.4
1921	140	177.2	+37.2	141.8	+1.8
1922	[2] 139	177.2	+38.2	141.8	+2.8

[1] Boll-weevil damage calculated as 10 per cent in 1920 and 20 per cent in 1921 and 1922.
[2] Estimated by Department of Agriculture on Sept. 25, 1922.

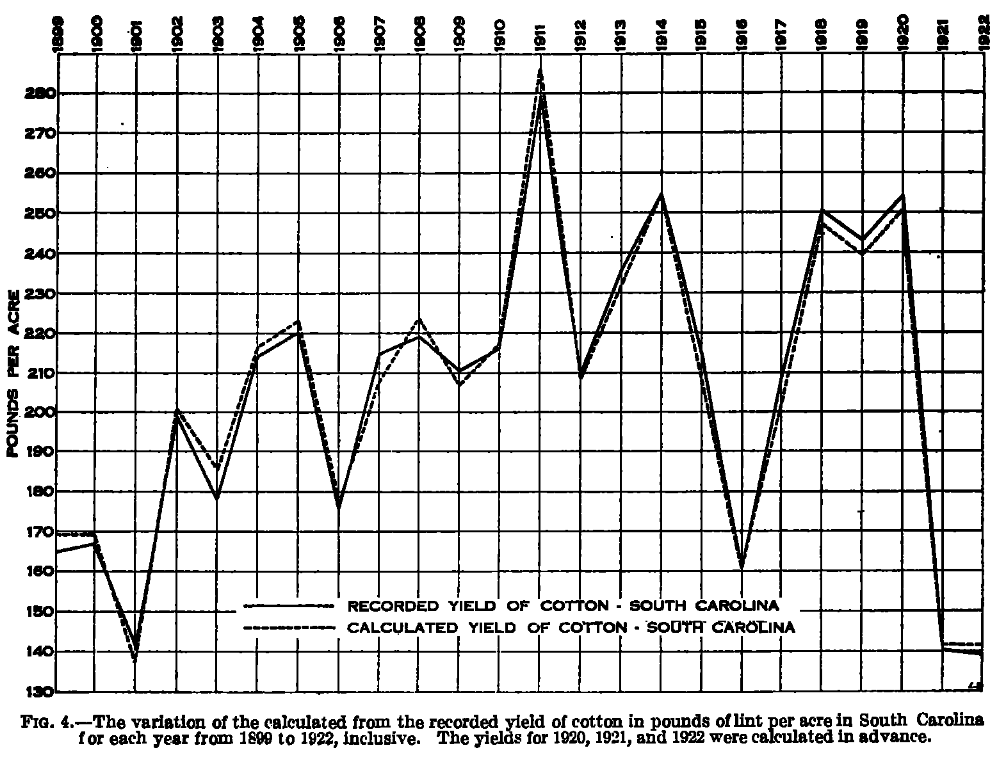

FIG. 4.—The variation of the calculated from the recorded yield of cotton in pounds of lint per acre in South Carolina for each year from 1899 to 1922, inclusive. The yields for 1920, 1921, and 1922 were calculated in advance.

ALLOWANCE FOR BOLL-WEEVIL DAMAGE.

Since South Carolina was entirely free from boll-weevil damage for most of the period covered by the data used in computing the constants of the regression equation, whereas such damage was considerable over the period of the test years, the comparatively large error between the actual and the estimated yield not only necessitates a correction for boll-weevil effects, but shows the soundness of the method, because a correction is required for the introduction of adverse crop effects not included in the investigation. In the absence of other exact data an allowance of 10 per cent for 1920 and 20 per cent for 1921 and 1922 brings the actual and calculated effects into close accord. We are satisfied that these allowances are fair ones and that the working reliability of the method and equation has been demonstrated.

The next step should be to apply these methods and equations to other oat, corn, and cotton States, and this will be done as soon as the data can be tabulated.

We are sure that the methods can be refined with more work, and also that they will need to be modified somewhat when working in districts with different climatic conditions. It seems to the writer, however, that the principle has been demonstrated and that after other important crop districts have been covered it will be possible to predict the yield of the important crops considerably before the harvesting time.

It will be seen in the studies noted above that although the weather must be taken into account up to about the harvest date for oats, the probable yield of corn can be determined by the end of July and of cotton at the end of June in the eastern part of the belt.

Undoubtedly the weather in July, and possibly August, must be considered in connection with cotton in the western part of the belt and that August may need to be taken into account in connection with corn in the central and western Great Plain States.

Figure 4 gives the variation of the calculated from the recorded yield of cotton in pounds of lint per acre in South Carolina for each year from 1899 to 1922, inclusive. The yields for 1920, 1921, and 1922 were calculated in advance.

THE DAILY QUANTITIES IN WHICH SUMMER PRECIPITATION IS RECEIVED.

By JOHN S. COLE, Agriculturist.

[U. S. Bureau of Plant Industry, Washington, D. C., November 15, 1922.]

SYNOPSIS.

The daily precipitation during the five months from April to August, inclusive, for the 12-year period from 1908 to 1919, inclusive, was studied at eight stations in the Great Plains and at Washington, D. C., Nephi, Utah, and Moro, Oreg. During 153 days of these months Washington had measurable precipitation on 55.8 days, the Great Plains on 41.7 days, Nephi on 26.3 days, and Moro on 21.8 days. Within limits, the quantity of precipitation is not determined by the number of days on which it occurs. In the Great Plains 82 per cent of the days having measurable precipitation have 0.50 inch or less and 45 per cent have 0.10 inch or less. In quantities from 0.05 inch up to a critical point, which is approximately 0.30 inch at Moro and Nephi, from 0.70 inch to 1.10 inches in the Great Plains, and 1.20 inches at Washington, the frequency of a given precipitation is inversely proportional to its amount. Above the critical point the decrease in frequency is more rapid than increase in amount. The number of precipitations below 0.05 inch increases with decreasing quantity but not in the same proportion.

In studying some of the results of the experiments in crop production conducted in the Great Plains by the Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry it became necessary to analyze the precipitation data in more detail than was afforded by monthly and seasonal totals. The points on which information was sought were (1) the frequency of precipitation and (2) the quantities of water received in precipitations of different amounts. The study was made on the precipitation for the five-month period from April to August, inclusive, for the 12 years from 1908 to 1919, inclusive. The eight field stations of the Bureau of Plant Industry, at which these studies of precipitation were made, are the Judith Basin station, near Moccasin, Mont.; Dickinson, N. Dak.; the Belle Fourche station, near Newell, S. Dak.; Akron, Colo.; North Platte, Nebr.; Hays, Kans.; Garden City, Kans.; and Amarillo, Tex. The North Platte record used in this study is the one from the rain gauge on the table where the dry-land experimental plats are located. All records were made from standard Weather Bureau rain gauges with free exposure and are a part of the records of the Biophysical Laboratory of the Bureau of Plant Industry obtained in cooperation with the Office of Dry-Land Agriculture Investigations. The five-month period from April to August, inclusive, was used because it is the period with which the study of the behavior of the grain crops is chiefly concerned. The study was made for 12 years because the eight stations selected for it had continuous records for that period; it seemed sufficiently long to give reliable averages and fairly smooth curves, and it was the period covered by the study of crops and soil moisture.

The precipitation is recorded in quantities received daily and consequently does not permit more refined study than of the number of days having precipitation of given quantities. In this paper a precipitation is therefore understood to be a day having precipitation of measurable quantity.

To afford comparison with other conditions the study was extended to include the Weather Bureau records of precipitation at Washington, D. C., as representative of humid conditions, and the records obtained at Nephi, Utah, and Moro, Oreg., in the cooperative work between the Office of Cereal Investigations and the agricultural experiment stations of those States and the Biophysical Laboratory of the Bureau of Plant Industry. These two stations are representative of the winter rainfall and dry summers of the intermountain dry-farming region.

The first study made of the data was a count of the number of precipitations in each of six groups, as follows: From 0.01 to 0.50 inch, from 0.51 to 1 inch, and then in groups of 1 inch up to 5 inches. There were none above 5 inches to be considered. The results of this study are shown in Table 1. To avoid fractions, the data in this table are shown on the basis of the total number in the 12 years during the months studied. The columns at the right show the average number of days each year having measurable precipitation in the 153 days from April 1 to August 31, inclusive, and the average precipitation during this period. Table 1 shows that the eight stations in the Great Plains have measurable precipitation on an average of 41.7 days during this period, or every 3⅔ days. The range is from 36.8 days at Garden City and Amarillo to 47.6 days at the Judith Basin station. During the same period Washington, D. C., had precipitation on 55.8 days; Nephi, Utah, on 26.3 days; and Moro, Oreg., on 21.8 days. Significant differences are shown between the different stations or sections of the